

****FULL TITLE****

*ASP Conference Series, Vol. **VOLUME**, **YEAR OF PUBLICATION***

****NAMES OF EDITORS****

Theoretical problems and perspectives

Francoise Combes

*Observatoire de Paris, LERMA, 61 Av. de l'Observatoire, F-75014
Paris, France*

Abstract. This talk tries to summarise where we are now, in the “nature and nurture” questions in galaxy formation and evolution, and briefly describe unsolved problems, and perspectives of progress.

1. Possibly solved questions

Throughout this meeting, there has been a lively debate about the mere definition of what is an isolated galaxy, and it appears that a consensus has arisen that although complete isolation does not exist, at least the most isolated objects can be identified. So the questions where an answer has been proposed in this conference are the following:

- Are there isolated galaxies in the universe? Robust definitions and criteria, involving relative separation of galaxies, in both space and velocities, have been proposed, ensuring isolation at least for time lapse of billion years (talk by Karachentseva, AMIGA contributions).
- Is there a void problem, i.e. do we see galaxies in the voids, as predicted by the standard Λ CDM theory and simulations (e.g. Peebles, 2001)? We have heard in several talks (Tinker, Croton) that the problem is solved, at least at zeroth order: environment is a secondary parameter in simulations. However, due to the morphology segregation and bias, we should see some dwarf galaxies in the voids, that are not there (Koribalski).
- The existence and life-time of compact groups (CG) have always been an issue; but genuine CG are an ideal location to study environmental effects. May be two thirds of apparent CG are only chance alignment (and one third only if selected in velocity, Mamon), the special dense environment of CG is visible in peculiar colors, star formation, morphology (McConnachie), and low fraction of broad line AGN (Dultzin, Martinez).
- How are formed isolated early-type galaxies (ETG)? are they the end evolution of fossil groups? 20% ETG lie in low density environment, some with X-ray haloes, some have recently assembled (Forbes); their evolution might depend more on halo mass than environment.

2. Remaining questions

Several issues remain to be solved in the standard galaxy formation scenario, which are intimately related to the environment. Let us mention successively how the luminosity function varies with environment, and whether the over-prediction of bright and faint galaxies could be solved, how the bimodality between red and blue galaxies, and in particular the mass limit separating the two varies with environment, how the galaxy density, through harassment and strangulation can produce star formation quenching, leading to downsizing. The problem of bulge-less galaxies depends strongly on environment, very large fraction of them are found in isolated galaxies.

2.1. Mass and light distribution function

One of the main problems encountered in the Λ CDM scenario (numerical and semi-analytical simulations) is the prediction of too many bright and too many faint galaxies (Baugh 2006, Eke et al 2006, Jenkins et al 2001). To avoid the formation of stars in dwarf haloes, models rely on star formation feedback. Gas is heated in dwarfs, but then falls in heavier haloes, which worsens the bright end problem. To limit the star formation and baryon infall in massive galaxies, requires AGN feedback (e.g. Somerville et al 2008). Croton & Farrar (2008) show how the luminosity function varies with environment: at first order, the profile with respect to mass is the same for high and low density, but all populations are 10 times lower in voids. The function is dominated by the blue late-type galaxies at the faint end. Due to the shift to low-mass galaxies in voids, the blue ones are then predominant.

The VIMOS deep survey (Ilbert et al 2006) reveals that at about half-life of the universe, the morphological segregation of galaxies according to over or under-dense regions is already pronounced. Nurture effects should act quite early or nature is important.

2.2. Bimodality

The distinction between red sequence and blue cloud galaxies in the SDSS (Baldry et al 2004) covers many parameters, essentially the star formation rate and history, but also dust, age, metallicity. The two classes are explained by two different formation mechanisms, with a separating stellar mass limit of $3 \cdot 10^{10} M_{\odot}$. The fraction in red sequence increases both with mass and environment (Baldry et al 2006).

An alternative interpretation is that star formation history depends on surface density (Kauffmann et al 2003). There is a transition in disk surface density ($300 M_{\odot}/pc^2$), where the gas begins to outflow, corresponding to the supernova escape velocity of about 100km/s.

The origin of the bimodality has been proposed in terms of gas accretion from external filaments: above a certain mass ($3 \cdot 10^{11} M_{\odot}$ in dark matter halo), the gas is not accreted cold, but is heated in shocks and has no time to cool, while below cold gas is accreted (Keres et al 2005, Dekel & Birnboim 2006). However, the bimodality is not well reproduced by semi-analytical models: there is an excess of blue bright objects, and red faint satellites (de Lucia al 2006).

2.3. Downsizing

The well-known paradox for hierarchical scenarios, i.e. that massive galaxies have the shortest formation timescales, might be interpreted in terms of environment. Comparing the star formation history of field and cluster ellipticals, the formation time is delayed in the field (de Lucia et al 2006). The hierarchical formation of the brightest galaxy in clusters have been followed by de Lucia & Blaizot (2007): most stars are formed before $z=5$, but the mass is mainly assembled after $z=0.5$ through dry mergers.

In a large SDSS sample, stellar ages and metallicities have been studied, with respect to mass and environment (Mateus et al 2007). In clusters, massive early-type galaxies are older and more metallic, they have formed at high redshifts; galaxy evolution is accelerated in denser environments, and proceeds via a nurture way.

2.4. Problem of bulgeless galaxies

One of the hard problems encountered by the hierarchical scenario is the high frequency of bulge-less spiral galaxies today. Those must not have experienced major mergers. Locally, about two thirds of the bright spirals are bulgeless, or have a light bulge (Kormendy & Fisher 2008, Weinzirl et al 2009). Surprising is the large frequency of edge-on superthin galaxies (Kautsch et al 2006). one third of galaxies are completely bulgeless. Among the SDSS sample, 20% of bright spirals are bulgeless until $z=0.03$ (Barazza et al 2008). The frequency is of course higher in low-density environment (talk by Karachentsev, this meeting).

These numbers are not compatible with the predicted bulge-to-total mass ratio predicted in semi-analytic models, with major mergers (Weinzirl et al 2009). In Λ CDM, a bulge-to-total mass ratio lower than 0.2 requires no merger since 10 Gyr (or last merger before $z=2$). The predicted frequency of bulge-less galaxies is 15 times lower than observed.

The solution might reside in the importance of cold gas accretion on galaxy mass assembly (Keres et al 2005). The relative fraction of mass accreted from cold gas in filaments is larger in low-mass haloes, and therefore in under-dense regions. Both observations and simulations reveal that most of the starbursts are due to smooth flows (e.g. Robaina et al 2009). Inflow rates are sufficient to assemble galaxy mass ($10\text{-}100\text{ M}_{\odot}/\text{yr}$). Gas accretion can occur at arbitrary angles, and form sometimes polar rings. Stanonik et al (2009) show such a gaseous polar disk, around a galaxy aligned along a wall between voids (cf van de Weygaert, this meeting and the winning poster!). Gas from the cosmic filaments is flowing to the wall, perpendicular to it.

3. Perspectives

We are now confident that the most isolated galaxies can and have been identified, and the respective roles of nature and nurture have been recently well highlighted.

- Nature is revealed by faster evolution and merging in over-dense regions, that will become clusters, while the nurture effects are obvious through strangulation, ram-pressure, harassment, once clusters are formed.

- Star formation and AGN feedback are necessary to fit the luminosity function of galaxies, and baryon fraction in stars.
- The downsizing paradox is partly due to environment, but semi-analytic models have still too many bright blue objects at $z=0$, and too many red faint satellites. May be gas accretion should not be stopped for these faint satellites, which would enhance also the green valley.
- The role of mergers might have been over-estimated with respect to gas accretion in galaxy mass assembly, and this could explain the bulge-less galaxy problem.

Acknowledgments. Many thanks to the organisers for the invitation to such a lively and friendly meeting.

References

- Baldry, I.K., Glazebrook, K., Brinkmann, J. et al.: 2004 ApJ 600, 681
 Baldry, I. K., Balogh, M. L., Bower, R. G. et al.: 2006 MNRAS 373, 469
 Baugh, C. M.: 2006 Reports on Progress in Physics 69, 3101
 Barazza, F. D., Jogee, S., Marinova, I.: 2008 ApJ 675, 1194
 Croton D., Farrar G.: 2008 MNRAS 386, 2285
 Dekel, A., Birnboim, Y., 2006 MNRAS 368, 2
 De Lucia, G., Springel, V., White, S. D. M. et al.: 2006 MNRAS 366, 499
 De Lucia, G., Blaizot, J.: 2007 MNRAS 375, 2
 Eke, V. R., Baugh, Carlton M. et al.: 2006 MNRAS 370, 1147
 Ilbert, O., Lauger, S., Tresse, L. et al.: 2006 A&A 453, 809
 Jenkins, A., Frenk, C. S., White, S. D. M. et al.: 2001 MNRAS 321, 372
 Kauffmann, G., Heckman, T. M., White, S. D. M. et al.: 2003 MNRAS 341, 54
 Kautsch, S. J., Grebel, E. K., Barazza, F. D., Gallagher, J. S.: 2006 A&A 445, 765
 Keres, D., Katz, N., Weinberg, D. H., Dave, R.: 2005 MNRAS 363, 2
 Kormendy, J., Fisher, D. B.: 2008 ASPC 396, 297
 Mateus, A., Sodre, L., Cid Fernandes, R., Stasinska, G.: 2007 MNRAS 374, 1457
 Peebles P.J.E.: 2001, ApJ 557, 495
 Robaina, A. R.; Bell, E. F.; Skelton, R. E. et al.: 2009 preprint, arXiv0907.3728
 Somerville, R. S., Hopkins, P. F., Cox, T.J. et al.: 2008 MNRAS 391, 481
 Stanonik, K., Platen, E., Aragn-Calvo, M. A. et al.: 2009 ApJ 696, L6
 Weinzirl, T., Jogee, S., Khochfar, S. et al.: 2009 ApJ 696, 411